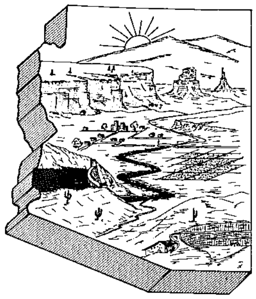

FIELDNOTES
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Windows to the Past: Fossils of the San Pedro Valley

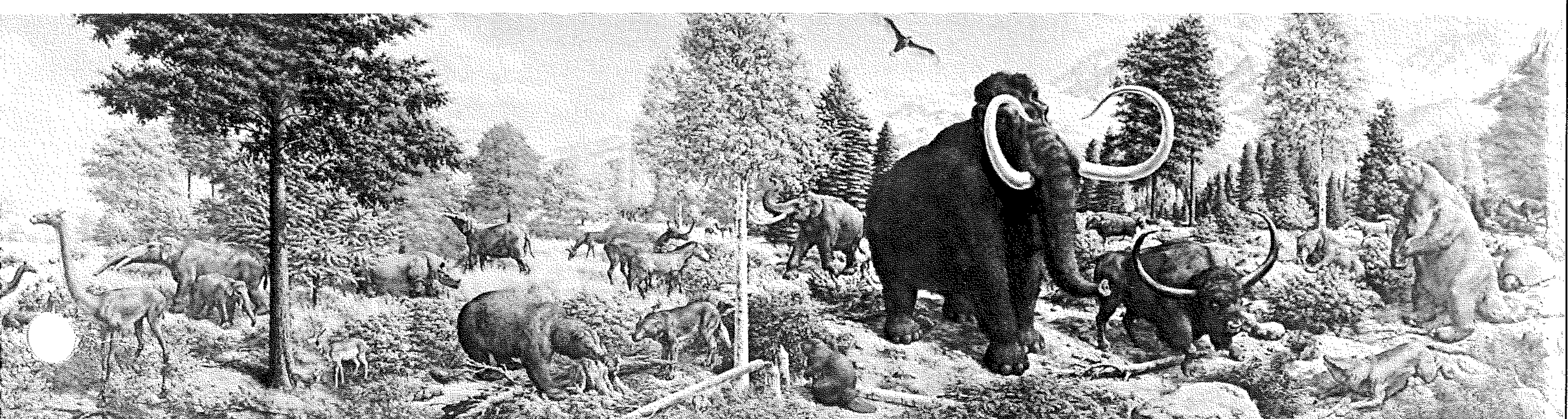

Figure 1. During the late Miocene and Pliocene, open-country animals were widespread across North America. Pronghorns, rhinos, and camels were plentiful (far left and center). The horse *Dinohippus* and the bear *Agriotherium* were common inhabitants of the San Pedro Valley in the early Pliocene. The Pleistocene Epoch in North America was the time of the great ice ages. The giant beaver *Castoroides* (center) and the long-horned bison (right center) were widespread. During this time, wooly mammoths and musk oxen (center) were common in high latitudes; megatheres (giant ground sloths) and armadillolike glyptodonts (right), which dispersed to North America from South America, were common in low latitudes. From the Age of Mammals Mural by Rudolph F. Zallinger, courtesy of the Peabody Museum of Natural History, Yale University, New Haven, Connecticut.

by Everett H. Lindsay

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A drive along U.S. Highway 80 between Benson and Bisbee in southeastern Arizona offers the traveler varied and enchanting vistas, wildlife, and vegetation. The San Pedro Valley, through which this highway passes, lies at the western edge of the Chihuahuan Desert.

Plants and animals at various times have "moved into" the San Pedro Valley from other areas; some may have evolved there. Their present association in the valley represents a unique (and temporary) biotic assemblage: one scene of a dynamic, ever-changing drama. The natural history of the San Pedro Valley represents a kaleidoscope of changing plant and animal life, as new species evolve and old species migrate or become extinct in response to widespread geologic and climatic changes (Figure 1).

The San Pedro Valley is a prime area for studying life sequences because its fossil record preserves more than 6 million years (m.y.) of biotic changes. The valley has one of the best late Cenozoic terrestrial sequences in North America and has yielded the best record of early man and extinct mammals known on the continent.

This article summarizes the geologic and fossil record of the San Pedro Valley since its development about 6.5 m.y. ago, and compares the past biota, preserved as fossils, with the flora and fauna now living in that area. Only through such studies can the natural history of an area be understood.

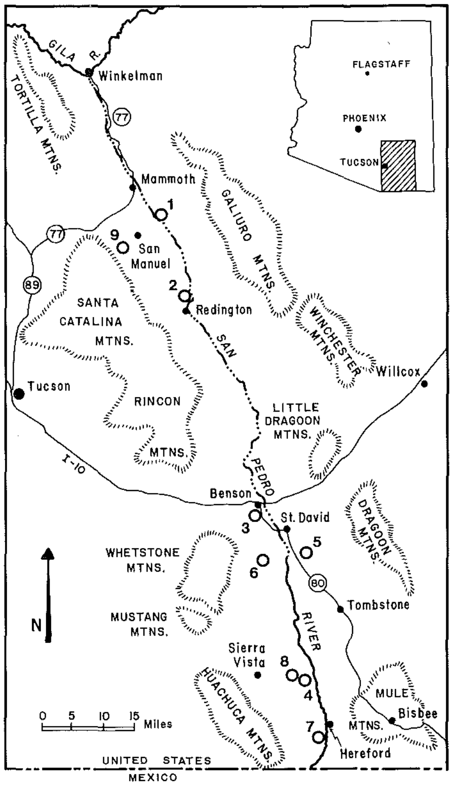
LATE CENOZOIC GEOLOGIC HISTORY

The San Pedro Valley extends from northern Sonora to the confluence of the San Pedro and Gila Rivers near Winkelman. It is bounded on the east (from south to north) by the Mule, Dragoon, Little Dragoon, Winchester, and Galiuro Mountains. It is bounded on the west (from south to north) by the Huachuca, Mustang, Whetstone, Rincon, Santa Catalina, and Tortilla Mountains (Figure 2).

This pattern of discontinuous, subparallel mountain ranges bounding a relatively linear (southeast to northwest) valley is characteristic of the Basin and Range geomorphic province of Arizona. The mountain ranges are uplifted blocks of the crust relative to the valley blocks. The discontinuous mountain ranges and sinuosity of the valleys suggest that this topography was developed over a long period of time by complex processes, rather than a single, simple geologic event.

Geologic data, supported by numerous radiometric age determinations on volcanic rocks, indicate that the existing basin-and-range topography was formed during the late Miocene, between 14 and 6 m.y. ago. This period of geologic change has been named the "Basin and Range disturbance" (Scarborough and Peirce, 1978). The Basin and Range disturbance, which is responsible for the formation of the San Pedro Valley and similar valleys in southern Arizona, has affected eight western States and represents an important episode in the history of the North American continent.

Sediments that accumulated after the San Pedro Valley was formed are called "basin-



1 Camel Canyon
2 Edgar Canyon
3 Benson
4 Wolf Ranch
5 Cal Tech, Curtis Ranch
6 California Wash
7 Lehner site
8 Murray Springs, Curry Draw
9 Deadman Cave

Figure 2. The San Pedro Valley. Numbered circles refer to fossil areas discussed in the text.

fill" sediments. These flat-lying sediments include the Quiburis and San Manuel Formations in the northern San Pedro Valley (Heindl, 1963) and the St. David Formation (Fm.) in the southern San Pedro Valley (Gray, 1967). Radiometric and paleomagnetic data indicate that the Quiburis Fm. was deposited between 6.5 and 4.5 m.y. ago (Damon and others, 1969; Lindsay and others, 1984). Similar data from the St. David Fm. indicate that it was deposited between 4.5 and 0.5 m.y. ago (Johnson and others, 1975; Tahirkheli and Naeser, 1975).

The Quiburis Fm. contains flat-lying mudstones, siltstones, and volcanic tuffs, with minor amounts of diatomites, sandstones, and pebbly conglomerates. Volcanic ashes are common and widely scattered. The St. David Fm. consists of flat-lying mudstones, siltstones, and discontinuous freshwater limestones, with minor amounts of sandstones, diatomites, and conglomerates.

The St. David Fm. spans the Pliocene/Pleistocene boundary. In southern Italy, this boundary has recently been redefined as 1.7 m.y. Paleomagnetic data from Curtis Ranch on the east side of the San Pedro Valley, just north of Tombstone, correlate precisely with data from the boundary in Italy, deep-sea cores, and many other terrestrial deposits on other continents. The San Pedro Valley, therefore, represents one of the best reference sections for late Cenozoic terrestrial strata in North America, including the Pliocene/Pleistocene boundary.

Evidence exists that the San Pedro Valley was once a closed trough that lacked external drainage. The change from internal to external drainage (i.e., from a closed valley to a valley with a stream flowing through it) is reflected in a change from fine-grained pond deposits to coarser, overlying stream deposits. External drainage developed in the northern San Pedro Valley after about 4.5 m.y. ago, and in the southern valley after about 1.5 m.y. ago.

Before the valley acquired through-drainage, there was an interval of relative calm, both geologically and climatically. This interval followed the Basin and Range disturbance, but preceded the large-scale climatic changes of the Pleistocene, or Ice Age. This time of tranquility is reflected in the uppermost part of the St. David Fm., which has well-developed paleosols, or ancient soil horizons. Development of soil profiles requires periods of relative geologic stability.

During the early Ice Age (1.7 to 1.0 m.y. ago), large-scale climatic changes produced alternating episodes of deep erosion and deposition along the San Pedro River (Morrison, in press). This pattern of events is reflected by a series of terraces along the river channel.

Toward the end of the Pleistocene, climatic changes decreased in magnitude; in turn, the degree of erosion and deposition by the San Pedro River diminished (Haynes, 1968, 1984). This was the time that early man appeared in the San Pedro Valley. Paleo-Indian remains from both the Clovis culture and the Cochise culture have been recorded from the valley (Haynes, 1970). Haynes (1970, 1984) noted that at least five of the authentic records of Clovis culture in North America occur in or near the San Pedro Valley. In fact, the valley has yielded the best fossil record of early man and extinct mammals known in North America.

LATE CENOZOIC LIFE

Terrestrial deposits and faunas in North America are correlated with North American land mammal ages. These biochronologic units are sequential, nonoverlapping intervals of time, each of which is characterized by an assemblage of fossil mammals. The youngest North American land mammal ages (in decreasing age) are the Hemphillian, Blancan, Irvingtonian, and Rancholabrean (Figure 3). Fossils from the Quiburis Fm. (Table 1) are correlated with the Hemphillian; fossils from the St. David Fm. (Table 2) are correlated with the Blancan and Irvingtonian. Deposits that overlie the St. David Fm. (Table 3) are correlated with the Rancholabrean and the Holocene. Fossils known from these deposits are listed in the tables and discussed below.

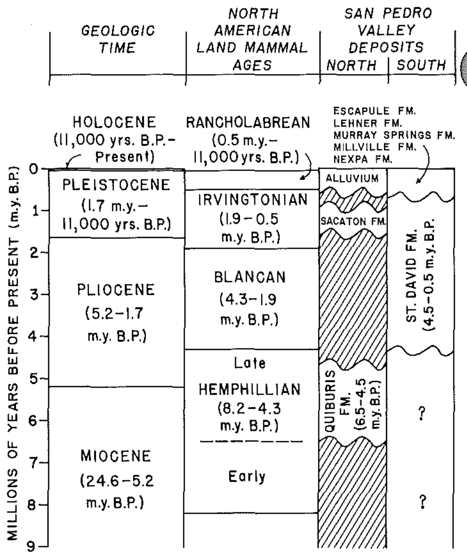


Figure 3. Geologic column showing age ranges of epochs, land mammal ages, and sediments that accumulated in the San Pedro Valley after its formation.

Quiburis Formation (late Hemphillian; 6.5 to 4.5 m.y. ago)

The earliest known record of life in the San Pedro Valley following its formation is from the Quiburis Fm. Fossils have been collected from this formation since 1941 by paleontologists from the American Museum of Natural History, and since about 1950 by paleontologists from the University of Arizona. Major fossil collections from the Quiburis Fm. are now housed at the American Museum in New York and at the University of Arizona in Tucson.

Most of the fossils known from the Quiburis Fm. have been found in two areas—Camel Canyon on the east side of the river near San Manuel, and Edgar Canyon on the west side of the river near Redington. These fossils include freshwater snails and clams, dissociated and unstudied fish and bird remains, 3 genera of lizards, and 25 genera of mammals (Table 1; Jacobs, 1973; Lindsay, 1978). Plants and other freshwater invertebrates were probably preserved in the Quiburis Fm. as well, but so far only the vertebrates have yielded adequate material for study.

During the late Hemphillian, bats, rabbits, squirrels, pocket mice, kangaroo rats, and deer mice lived in the San Pedro Valley—an assemblage comparable to that living in the valley today, although all genera but one (*Perognathus*, the pocket mouse) are different. Jacobs (1977) described three new genera and six new species of rodents. One family of extinct rodents (*Eomyidae*) has been found in the Quiburis Fm.

The carnivore fossils from the Quiburis Fm. are diverse, which suggests that a diverse group of herbivorous mammals were also present in the same area.

Wolverines and bears were widespread in North America during the late Hemphillian. They were the largest known carnivores of this time. Both probably originated in Asia and migrated to North America about 6.5 m.y. ago (Harrison, 1981; Lindsay and others, 1984). Grizzly bears were commonly encountered in the San Pedro Valley and surrounding mountains during the 1800's (Davis, 1982).

Other carnivores recorded from the Quiburis Fm. include a fox, coyote, marten, badger, ringtail, bobcat, stabbing cats, and dogs.

The Quiburis horse *Dinohippus* had foot and skull characteristics similar to those of modern horses. One of the Hemphillian species of *Dinohippus* probably gave rise to the modern horse *Equus* about 4 m.y. ago. Unfortunately, deposits and fossils in the 5- to 4-m.y. interval are poorly represented in the San Pedro Valley. Therefore, it is unlikely that a horse transitional between *Dinohippus* and *Equus* would be found there.

During the late Miocene and the Pliocene, pronghorns and camels were common and widespread in North America, including the San Pedro Valley. Mastodons, which are now extinct, were the largest herbivores to live in the valley, but were rare during its early history.

In summary, animals that lived in the San Pedro Valley during the Hemphillian were basically similar to those found in other parts of North America during this time.

Table 1. Biotic Record of the Quiburis Formation. Sources: Jacobs (1973) for molluscs and small mammals; T. R. Van Devender (unpublished notes) for reptiles; E. H. Lindsay, R. H. Tedford, and B. E. Taylor (unpublished notes) for large mammals. Locality abbreviations: R= Redington; C=Camel Canyon.

Mollusca		
Fossaria parva (aquatic snail)	R	
Gyraulus parvus (aquatic snail)	R	
Pisidium cf. *walkeri* (clam)	R	
Pisces		
small indeterminate fish		C
Reptilia		
?Leiocephalus sp. (iguanid lizard)	R	
?Sceloporus sp. (fence lizard)	R	
Cnemidophorus sp. (whiptail lizard)	R	
Aves		
indeterminate bird		C
Mammalia		
Chiroptera		
indeterminate bat	R	
Lagomorpha		
Hypolagus sp. (rabbit)	R	
Rodentia		
?Tamias sp. (chipmunk)	R	
Spermophilus sp. (squirrel)	R	
Ronquillomys wilsoni (eomyid)	R	
Perognathus mclaughlini (pocket mouse)	R	
Perognathus henryredfieldi (pocket mouse)	R	
Prodipodomys kansensis (kangaroo rat)	R	
?Copemys vasquezi (cricetid)	R	
Paronychomys lemredfieldi (cricetid)	R	
Paronychomys tuttlei (cricetid)	R	
Galushamys redingtonensis (cricetid)	R	
Carnivora		
Vulpes stenognathus (fox)	R	C
Canis davisi (coyote)	R	C
Canis cf. *lepophagus* (dog)	R	
Osteoborus sp. (dog)	R	C
Martes sp. (marten)	R	
Pliotaxidea sp. (badger)	R	
Plesiogulo sp. (wolverine)	R	
Bassariscus sp. (ringtail)		C
Agriotherium cf. *gregorii* (bear)	R	C
Machairodus sp. (stabbing cat)	R	C
Adelphailurus sp. (stabbing cat)	R	
Felis (Lynx) sp. (bobcat)	R	
Proboscidea		
Pliomastodon sp. (mastodon)		C
Perissodactyla		
Dinohippus sp. (single-toed horse)	R	C
Artiodactyla		
Hemiauchenia sp. (llama)	R	C
Megatylopus sp. (camel)	R	C
Texoceros sp. (pronghorn)	R	C

St. David Formation (Blancan and Irvingtonian; 4.5 to 0.5 m.y. ago)

The St. David Fm. has produced a more complete picture of fossil life in the San Pedro Valley than has the Quiburis Fm. The record of plant life from the St. David Fm., however, is still very inadequate. Numerous attempts to obtain pollen have proven unsuccessful. The scouring rush is a plant frequently recovered from diatomaceous strata that also yield numerous fossils of small mammals, reptiles, and amphibians. Scouring rush can be found today near springs and perennial streams high in the Huachuca Mountains. Gray (1960) reported fossil pollen from deposits near Safford that included pine, fir, oak, alder, spruce, hackberry, cattail, and sagebrush plants. The Safford fossil pollen indicates that a pine forest may have existed there, with occasional fir or spruce trees nearby. A similar environment may have existed in the San Pedro Valley. The diversity of invertebrate and vertebrate fossils discovered in the St. David Fm. suggests that plant life was also diverse.

Table 2 lists fossils from five separate areas—Benson, Wolf Ranch, Cal Tech, California Wash, and Curtis Ranch—to indicate temporal and geographic change in the fauna from the St. David Fm. The Benson fauna is about 3 m.y. old; the Wolf Ranch, Cal Tech, and California Wash faunas are about 2.5 m.y. old; and the Curtis Ranch fauna is about 1.9 m.y. old. Fossils from the Benson and Curtis Ranch areas are more widely known than from the other areas.

Nine genera of aquatic crustaceans (*Ostracoda*), 1 species of clams, and 16 species of snails have been reported from the St. David Fm. (Gray, 1965; Taylor, 1966). Unidentified fish remains have also been recovered (Harrison, 1978). Five species of amphibians have been recovered, including a tiger salamander, toad, spadefoot toad, tree frog, and leopard frog. All of these amphibians are closely related to, if not identical with, species that now inhabit the mountains surrounding the San Pedro Valley, especially the southern, wetter areas near the Mexican border.

Mud turtles, box turtles, and giant tortoises were common in the valley. During the late Cenozoic, giant tortoises were widely distributed throughout the western United States. They became extinct in North America at the end of the Pleistocene. The desert tortoise (*Gopherus*), which is less common in the St. David Fm., now occupies some of the area that the giant tortoise inhabited millions of years ago.

During the last 3 m.y., the small-reptile fauna of the San Pedro Valley has changed little morphologically; it has changed in composition, however, because of ecologic-climatic shifts during that interval. Five species of lizards and seven species of snakes, all clearly related to modern genera or species, have been found in the St. David Fm.

Eleven species of fossil birds have been identified from the St. David Fm., six of which are water birds (i.e., grebe, teal duck, tree duck, goose, gallinule, and sandpiper; Wetmore, 1924).

Two species of the shrew *Sorex* have been found in the St. David Fm. The only shrew inhabiting the San Pedro Valley today is the desert shrew *Notiosorex crawfordi*. Bats are very common in the valley today, and were probably common when the St. David Fm. was being deposited. Bats are rarely preserved in fossil deposits, however; only two specimens have been found in the St. David Fm. Fossil remains of *Glyptotherium*, an armadillolike mammal whose ancestry was in South America, have been found in the California Wash and Curtis Ranch areas of the valley.

Rabbits became very diverse in North America about 3 m.y. ago, during the time the St. David Fm. was being deposited. At least seven species from five genera of rabbits have been recovered from the St. David Fm. *Hypolagus* is a relatively primitive rabbit, which appeared in North America during the middle Miocene, about 17 m.y. ago; *Sylvilagus* is the modern cottontail. The fossil record of the St. David Fm., therefore, reflects the shift from primitive to modern rabbits.

Several species of squirrels probably lived in the San Pedro Valley 3 m.y. ago, but only two species have been identified. Beavers were relatively common throughout North America during this time, but are poorly represented in the St. David Fm. Beavers were trapped from the San Pedro River and other streams in Arizona prior to about 1850 (Davis, 1982). Fossils from three species of gophers have been found in the St. David Fm. The genus *Geomys* is now widespread in North America but does not inhabit Arizona, although it is relatively common in fossil deposits in the San Pedro Valley.

Rodents were diverse and common during the late Pliocene. Among those that inhabited the San Pedro Valley were pocket mice, kangaroo rats, cotton rats, packrats, a lemming, a pine vole, and a muskrat. The

Table 2. Biotic Record of the St. David Formation. Sources: Gray (1965) for ostracods; Taylor (1966) for molluscs; Brattstrom (1955) and T. R. Van Devender (unpublished notes) for amphibians and reptiles; Wetmore (1924) for birds; E. H. Lindsay (unpublished notes) for mammals. Locality abbreviations: B=Benson; WR=Wolf Ranch; CT=Cal Tech; CW=California Wash; CR=Curtis Ranch.

	B	WR	CT	CW	CR
Plants					
diatoms	X	X		X	
charophyte algae	X			X	
Equisetum (scouring rush)	X			X	
Ostracoda (aquatic crustaceans)					
Cypridopsis cf. *vidua*				X	
Limnocythere cf. *staplini*				X	
Limnocythere sp.				X	
Candona cf. *renoensis*				X	
Candona sp. A				X	
Candona sp. B				X	
?Candoniella sp.				X	
?Heterocypris sp.				X	
?Cyclocypris sp.				X	
Potamocypris sp.				X	
Cyprideis sp.				X	
Darwinula sp.				X	
Mollusca					
Pisidium casertanum (clam)	X				
Fossaria dalli (aquatic snail)	X				
Lymnaea caperata (aquatic snail)	X				
Lymnaea cf. *elodes* (aquatic snail)	X				
Bakerilymnaea bulimoides (aquatic snail)	X				
Gyraulus parvus (aquatic snail)	X				
Promenetus exacuous (aquatic snail)	X				
Promenetus umbilicatellus (aquatic snail)	X				
Physa virgata (aquatic snail)	X				
Gastrocopta cristata (terrestrial snail)	X				
Gastrocopta tappaniana (terrestrial snail)	X				
Pupoides albilabris (terrestrial snail)	X				
Vertigo milium (terrestrial snail)	X				
Vertigo ovata (terrestrial snail)	X				
cf. *Succinea* (terrestrial snail)	X				
Deroceras aenigma (slug)	X				
Hawaiia minuscula (terrestrial snail)	X				
Pisces					
indeterminate small fish		X		X	
Amphibia					
Ambystoma tigrinum (tiger salamander)	X			X	
Scaphiopus hammondi (spadefoot toad)				X	
Bufo alvarius (toad)	X			X	
Hyla eximia (tree frog)				X	
Rana sp. (leopard frog)				X	
Reptilia					
Kinosternon flavescens arizonense (mud turtle)	X				X
Terrapene cf. *ornata* (box turtle)	X				X
Terrapene sp. (box turtle)				X	
Gopherus whitlockensis (tortoise)	X				
Geochelone sp. (giant tortoise)	X				X
Eumeces sp. (skink)				X	
Cnemidophorus sp. (whiptail lizard)				X	
Crotaphytus sp. (collared lizard)	X				
Phrynosoma sp. (horned lizard)				X	
Sceloporus sp. (fence lizard)				X	
Coluber sp. (racer snake)				X	X
Pituophis melanoleucus (bull snake)				X	
Masticophis sp. (whipsnake)				X	
Lampropeltis intermedius (kingsnake)				X	X
Natrix sp. (water snake)					X
Thamnophis sp. (garter snake)				X	
Crotalus cf. *molossus* (rattlesnake)				X	
Aves					
Podicipedidae					
"Colymbus" sp. (grebe)	X				
Anatidae					
Querquedula sp. (teal duck)	X				
Dendrocygna eversa (tree duck)	X				
Anabernicula miniscula (goose)	X				
anatid indeterminate	X				
Meleagridae					
Meleagris cf. *progenes* (turkey)	X				
Phasianidae					
Colinus sp. (quail)	X				
Rallidae					
Gallinula sp. (gallinule)	X				
Scolopacidae					
Micropalama hesternus (sandpiper)	X				
Columbidae					
Columba micula (pigeon)					X
Corvidae					
Corvus sp. (crow)	X				
Fringillidae					
Junco sp. (junco)	X				
fringilid indeterminate	X				X
Mammalia					
Soricidae					
Sorex taylori (shrew)				X	
Sorex sp. (shrew)		X			
Vespertilionidae					
Simonycteris stocki (bat)		X	X		
Glyptotheriidae					
Glyptotherium arizonae (glyptothere)				X	X
Leporidae					
Hypolagus nr. *H. limnetus* (rabbit)	X				
Aluralagus bensonensis (rabbit)	X				
Aluralagus virginiae (rabbit)					X
Notolagus cf. *lepusculus* (rabbit)		X			
Notolagus cf. *velox* (rabbit)	X				
Nekrolagus progessus (rabbit)	X	X			
Sylvilagus sp. (cottontail)				X	X
Sciuridae					
Spermophilus bensoni (squirrel)	X	X		X	
Spermophilus cochisei (squirrel)					X
Castoridae					
Castor sp. (beaver)					X
Geomyidae					
Geomys minor (gopher)	X	X			
Geomys persimilis (gopher)		X		X	X
Cratogeomys bensoni (pocket gopher)	X				
Heteromyidae					
Perognathus pearlettensis (pocket mouse)		X			
Perognathus gidleyi (pocket mouse)		X			
Perognathus sp. (pocket mouse)	X			X	X
Prodipodomys minor (kangaroo rat)	X	X			
Prodipodomys idahoensis (kangaroo rat)		X		X	
Dipodomys gidleyi (kangaroo rat)					X
Cricetidae					
Calomys (Bensonomys) arizonae (vesper mouse)	X	X		X	X
Peromyscus sp. (deer mouse)		X			X
Baiomys minimus (pigmy mouse)	X	X			
Baiomys brachygnathus (pigmy mouse)		X			X
Onychomys bensoni (grasshopper mouse)	X	X			
Onychomys pedroensis (grasshopper mouse)					X
Sigmodon medius (cotton rat)	X	X			
Sigmodon minor (cotton rat)				X	X
Sigmodon curtisi (cotton rat)		X		X	X
Neotoma fossilis (pack rat)	X				
Neotoma sp. (pack rat)	X	X			X
Synaptomys (Metaxomys) sp. (lemming)				X	
Pliophenacomys sp. (pine vole)	X				
Ondatra idahoensis (muskrat)				X	X
Erethizontidae					
Coendou stirtoni (tree porcupine)		X			
Hydrochoeridae					
Neochoerus sp. (capybara)			X		
Canidae					
Canis edwardsi (wolf)					X
Canis sp. (dog)	X				
cf. *Borophagus* sp. (dog)	X				
Mustelidae					
Spilogale pedroensis (spotted skunk)					X
Felidae					
Panthera onca (jaguar)					X
Felis sp. (cat)	X				
Gomphotheriidae					
Cuvieronius bensonensis (gomphothere)	X			X	
Stegomastodon arizonae (gomphothere)		X	X		X
Equidae					
Nannippus phlegon (three-toed horse)	X	X			
Equus sp. (single-toed horse)	X	X	X	X	X
Tayassuidae					
Platygonus sp. (peccary)	X		X		X
Camelidae					
Hemiauchenia sp. (llama)	X				X
Camelops sp. (camel)	X	X		X	X
Cervidae					
Odocoileus sp. (deer)	X	X			
Antilocapridae					
Texoceros sp. (pronghorn)	X				
Capromeryx gidleyi (pronghorn)					X

tree porcupine and capybara were rodent immigrants from South America; the San Pedro Valley marks (or limits) their appearance in North America.

Among the carnivores, dogs, cats, and a skunk have been found in the St. David Fm. *Borophagus* was a bone-crushing dog, resembling hyenas of the Old World. *Panthera onca* was the common large fossil jaguar of North America. Bears may have inhabited the San Pedro Valley 3 m.y. ago, but no fossils have yet been found from this time.

Gomphotheres, elephantlike mammals, appeared in North America about 16 m.y. ago, during the middle Miocene, and became extinct during the Pleistocene. About 3 m.y. ago, they were the largest land mammals in North America. Fossils of the last two genera of gomphotheres to survive in North America (*Cuvieronius* and *Stegomastodon*) have been found in the San Pedro Valley.

The horse *Nannippus* was the last surviving three-toed horse in North America. It was much smaller than the single-toed horse in the valley at that time (*Equus*).

The fossil peccary *Platygonus* probably gave rise (through a series of species) to the modern collared peccary that now lives in the valley. Peccaries have a relatively long record in North America; they appeared during the Oligocene, 38 to 37 m.y. ago. Their numbers, however, were never very abundant. Peccaries were often recorded by travelers in the San Pedro Valley during the 1800's (Davis, 1982).

Camels also had a long history in North America, appearing in the late Eocene (53 m.y. ago), and were confined to North America until the late Pliocene. The llama *Hemiauchenia* probably dispersed to South America about the same time that the tree porcupine, capybara, and *Glyptotherium* were dispersing to North America from South America. *Hemiauchenia* is a common fossil in the San Pedro Valley, although the remains are usually fragmentary. Fossils from the larger camel species (*Camelops*), however, are scarce.

Two genera of pronghorns have been found in the St. David Fm. Pronghorns were very common in North America during the late Miocene. They diversified during the Pliocene (fossils from seven genera have been found on the continent), then declined to the single species of today, *Antilocapra americana*. *Antilocapra americana* was widespread in Arizona and commonly encountered in the San Pedro Valley prior to farming in that area. One genus found in the St. David Fm. (*Capromeryx*) may have given rise to the modern pronghorn.

Late Pleistocene (Rancholabrean; 0.5 m.y. to 11,000 years ago)

Fine-grained sediments that overlie the St. David Fm. (or equivalent strata) are scattered throughout the San Pedro Valley. Some of these strata, especially in the southern valley, have produced a diverse record of late Pleistocene life. Late Pleistocene and Holocene biota, as well as modern biota of the San Pedro Valley, are shown in Table 3.

The late Pleistocene record of plants in the San Pedro Valley is known primarily from fossil pollen found in the extreme southern part of the valley. Pollen records can be misleading because pollen is often carried by wind far beyond the area where the plants grow, and plants that are not pollinated by the wind, such as cacti, are poorly represented. Pollen from the late Pleistocene and Holocene flora includes numerous plants that no longer live in the San Pedro Valley (e.g., pine and juniper), and lacks many plants that do (e.g., paloverde, catclaw, and creosotebush; Table 3).

Fossil pollen found at the Lehner "early-man" site near Hereford shows a decline in pine, oak, juniper, cheno-am, grass, and sedge spores near the Pleistocene/Holocene boundary, and an increase in short-spine compositae such as annual flowers. A similar change has been recorded from the Murray Springs "early-man" site near Sierra Vista. This shift suggests that a change toward warmer and drier climates occurred after about 11,000 years ago. As noted above, pollen records may not accurately reflect the local vegetation. Pollen is much more abundant (and reliable) in southern Arizona in sediments younger than 10,000 years. Paleoclimate interpretations based on pollen in deposits older than 10,000 years are suspect.

Fossil snails are very abundant near Murray Springs. In sediments older than 11,000 years, 30 terrestrial and 13 aquatic molluscs have been identified. Twenty-two (73 percent) of the terrestrial species and five (38 percent) of the aquatic species currently live in the San Pedro drainage area, usually at higher elevations. Eighteen species now living in the valley, however, have no fossil record there. Mollusc fossils suggest that varied and shifting habitats existed in the area of Murray Springs, including desertscrub—grassland, oak woodland, oak chaparral, pine forest, and ponds. The fossil record for molluscs in the San Pedro Valley suggests that wetter and possibly cooler climates existed near the end of the Pleistocene, prior to 11,000 years ago.

Numerous vertebrate fossils from the late Pleistocene have been found near Curry Draw (Murray Springs Arroyo), Sierra Vista, and Deadman Cave near San Manuel. These include unidentified fish, 3 toads, a frog, 13 lizards, 12 snakes, and 13 birds. Mammal fossils include a shrew, 2 bats, a ground sloth, 2 rabbits, 5 squirrels, a gopher, 5 heteromyid rodents, 9 cricetid rodents, a wolf, a ringtail, 2 skunks, 2 cats, a mastodon, an elephant, a horse, a tapir, 2 camels, a deer, and 2 bovids. It is interesting that turtles, beavers, bears, peccaries, and pronghorns are absent from this rather diverse assemblage.

Of the 31 late Pleistocene mammal genera recorded from the San Pedro Valley, only 9 (sloth, vole, mastodon, elephant, tapir, llama, camel, ox, and bison) do not currently live there. Fossils of the Mexican ground squirrel have been discovered at Curry Draw; its closest habitat today is the Rio Grande Valley near El Paso. Only one species, a cotton rat (*Sigmodon curtisi*), is extinct.

Holocene (11,000 years ago to present)

Holocene life of the San Pedro Valley is best recorded in fine-grained alluvial deposits near Murray Springs and Lehner Ranch. Correlation of these deposits is now highly refined (and revised) because of detailed stratigraphic analysis and radiocarbon dating (C. V. Haynes, personal communication, 1984). Fossil pollen found near Murray Springs in units A through D, now correlated with the 4,000- to 6,000-year interval, includes abundant cheno-am, grass, pine, and sedge spores, and a low, but increasing number of spores from short-spine compositae. In contrast, pollen from older sediments (unit L) in the Lehner ranch area (8,000 to 9,500 years ago) shows a high, but declining abundance of short-spine compositae, a slight increase in grasses, and few pines, cheno-ams, and sedges. It appears that fairly significant changes were occurring in the vegetation of the San Pedro Valley during the early Holocene.

Younger sediments at Murray Springs and Lehner Ranch are more similar to each other. They contain abundant, increasing amounts of grass and cheno-am pollen; high, but decreasing, amounts of short-spine compositae; and few pine and sedge spores.

Mehringer and Haynes (1965) interpreted Holocene pollen from Lehner Ranch to indicate gradual development of a desert-grassland environment following a colder and wetter climate during the late Pleistocene (prior to 11,000 years ago). Mehringer and others (1967) interpreted Holocene pollen from Murray Springs to reflect increasing moisture (and ponding), with subsequent expansion of grassland and woodland about 5,000 years ago. Local ponding continued in the Murray Springs area until about 4,000 years ago.

Van Devender (1977) concluded, on the basis of radiocarbon-dated plant remains recovered from packrat middens, that woodland communities thrived during the Holocene in what are now southwestern deserts. Prior to 8,000 or 9,000 years ago, juniper, shrub oak, pinyon pine, and mountain mahogany grew in the areas of the Chihuahuan and Sonoran Deserts; however, many plants now common in the Chihuahuan Desert (e.g., creosotebush, lechuguilla, and ocotillo) and the Sonoran

Table 3. Late Pleistocene, Holocene, and Modern Life in the San Pedro Valley. Sources: Mehringer and Haynes (1965) and Mehringer and others (1967) for pollen; Mead (1977) and Bequaert and Miller (1973) for molluscs; Lowe (1976), Cockrum (1976), Lindsay (1978), and Mead and others (1984) for vertebrates. Abbreviations: P=late Pleistocene; H=Holocene; R=Recent (since about 1700 A.D.)

Plants (pollen only)			
Pinus (pine)	P	H	R
Juglans (walnut)	P	H	
Juniperus (juniper)	P	H	R
Celtis (hackberry)	P	H	R
Ephedra (Mormon tea)	P	H	R
Alnus (alder)		H	
Fraxinus (ash)		H	
Typha (cattail)		H	
Graminae (grasses)	P	H	R
Sambucus (elderberry)	P		
Cyperaceae (sedges)	P	H	R
Euphorbia (spurge)	P	H	R
Liliaceae (lilies)		H	
Rhamnaceae (buckthorn)		H	
Quercus (oak)	P	H	R
Eriogonum (wild buckwheat)	P	H	R
Polygonum (smart weed)		H	
Chenopodiaceae (goosefoot)	P	H	R
Tidestromia (espanta vaqueras)	P	H	
Nyctaginaceae (four-o'clock)	P	H	R
Brayulinea (mat weed)		H	
Salix (willow)			R
Kallstroemia (summer poppy)	P	H	R
Onagraceae (evening primrose)	P	H	
Malvaceae (mallow)	P	H	R
Prosopis (mesquite)		H	R
Plantago (plantain)		H	
Hedyotis (madder)	P	H	
Cruciferae (mustard)		H	
Dodonaea viscosa (hop bush)		H	
Umbelliferae (parsley)	P		
Artemisia (sagebrush)	P	H	R
Liguliflora (composite)	P	H	R
Mollusca			
Thysanophoridae (terrestrial snails)			
Thysanophora hornii			R
Microphysual ingersollii			R
Euconulidae (terrestrial snails)			
Euconulus fulvus	P	H	R
Zontidae (terrestrial snails)			
Retinella (Glyphyalinia) indentata			R
Nesovitrea hammonis electina	P	H	
Hawaiia minuscula	P	H	R
Zonitoides arboreus	P		R
Striatura meridionalis			R
Vitrinidae (terrestrial snails)			
Vitrina pellucida alaskana			R
Limacidae (terrestrial slugs)			
Deroceras laeve	P	H	R
Enodontidae (Punctidae; terrestrial snails)			
Discus cronkhitei	P		R
Discus shimekii			R
Helicodiscus eigenmanii			R
Helicodiscus singleyanus	P	H	R
Punctum californicum	P		R
Radiodiscus millecostatus			R
Succineidae (terrestrial snails)			
Succinea sp.	P	H	R
Oxyloma sp.	P	H	
Pupillidae (terrestrial snails)			
Gastrocopta pentodon	P	H	R
Gastrocopta pilsbrayana			R
Gastrocopta quadridens			R
Gastrocopta ashmuni			R
Gastrocopta cochisensis			R
Gastrocopta prototypus	P		R
Gastrocopta dalliana			R
Gastrocopta cristata	P	H	R
Gastrocopta pellucida		H	R
Gastrocopta armifera	P		
Chaenaxis tuba			R
Pupoides albilabris	P	H	R
Pupoides hordaceus	P		R
Pupilla blandii	P		R
Pupilla muscorum	P	H	
Pupilla hebes	P		R
Pupilla syngenes	P	H	R
Vertigo milium	P	H	R
Vertigo ovata	P	H	R
Vertigo gouldii	P		R
Vertigo modesta			R
Vertigo berryi	P	H	
Vertigo elatior	P		
Vertigo ventricosa	P	H	
Columella columella			R
Valloniidae (terrestrial snails)			
Vallonia perspectiva	P	H	R
Vallonia cyclophorella	P		R
Vallonia gracilicosta	P		
Cochlicopidae (Cionellidae; terrestrial snails)			
Cochlicopa lubirca	P		R
Lymnaeidae (aquatic snails)			
Fossaria bulimoides techella	P		
Fossaria caperata	P		
Fossaria obrussa	P	H	
Fossaria parva	P	H	R
Fossaria modicella	P		
Physidae (aquatic snails)			
Physa virgata	P	H	R
Physa humerosa	P		
Planorbidae (aquatic snails)			
Gyraulus parvus	P	H	R
Helisoma tenue			R
Drepanotrema aeruginosum			R
Ancylidae (freshwater limpets)			
Laevapex californica	P		
Hydrobiidae (aquatic snails)			
Fontelicella cf. *longingua*	P		R
Sphaeriidae (freshwater clams)			
Pisidium casertanum	P	H	R
Pisidium compressum	P	H	
Pisidium walkeri	P	H	
Pisces			
Cyprinidae			
Ptychocheilus lucius (Colorado squawfish)			R
Catostomidae			
Catostomus latipinnis (flannelmouth sucker)			R
Cyprinodontidae			
Cyprinodon macularius (desert pupfish)			R
Pisces, indeterminate genus	P		
Amphibia			
Pelobatidae			
Scaphiopus couchi (Couch's spadefoot toad)	P		R
Scaphiopus hammondi (western spadefoot toad)			R
Bufonidae			
Bufo alvarius (Colorado River toad)			R
Bufo woodhousei (Woodhouse's toad)	P		R
Bufo cognatus (Great Plains toad)			R
Bufo punctatus (red-spotted toad)			R
Hylidae			
Hyla arenicolor (canyon tree frog)			R
Ranidae			
Rana pipiens (leopard frog)			R
Rana sp. (frog)	P		
Reptilia			
Kinosternidae			
Kinosternon sonoriense (Sonora mud turtle)			R
Emydidae			
Terrapene ornata (western box turtle)			R
Testudinidae			
Gopherus agassizi (desert tortoise)			R
Helodermatidae			
Heloderma suspectum (Gila monster)	P		R
Gekkonidae			
Coleonyx variegatus (banded gecko)			R
Iguanidae			
Crotaphytus collaris (collared lizard)	P		R
Gambelia wislizeni (leopard lizard)			R
Holbrookia maculata (earless lizard)	P		R
Holbrookia texana (earless lizard)	P		R
Callisaurus draconoides (zebra-tailed lizard)	P		R
Sceloporus scalaris (bunch-grass lizard)			R
Sceloporus jarrovi (mountain spiny lizard)			R
Sceloporus undulatus (fence lizard)	P		R
Sceloporus clarki (spiny lizard)	P		R
Sceloporus magister (spiny lizard)	P		R
Urosaurus ornatus (tree lizard)	P		R
Uta stansburiana (side-blotched lizard)			R
Phrynosoma douglassi (short-horned lizard)	P		R
Phrynosoma cornutum (Texas horned lizard)			R

Table 3, continued.

Phrynosoma modestum (horned lizard)	P	R
Phrynosoma solare (regal horned lizard)	P	R
Scincidae		
Eumeces callicephalus (mountain skink)		R
Eumeces obsoletus (Great Plains skink)		R
Teidae		
Cnemidophorus burti (Sonora whiptail lizard)		R
Cnemidophorus arizonae (Arizona whiptail)		R
Cnemidophorus tigris (western whiptail)		R
Cnemidophorus sp. (whiptail)	P	
Anguidae		
Gerrhonotus kingi (Arizona alligator lizard)		R
Leptotyphlopidae		
Leptotyphlops dulcis (Texas blind snake)		R
Leptotyphlops humilis (western blind snake)		R
Colubridae		
Thamnophis eques (Mexican garter snake)		R
Thamnophis cyrtopsis (black-necked garter snake)		R
Thamnophis marcianus (checkered garter snake)		R
Heterodon nascius (western hognose snake)		R
Masticophis bilineatus (Sonora whipsnake)		R
Masticophis flagellum (whipsnake)		R
Masticophis sp. (whipsnake)	P	
Salvadora grahamiae (mountain patch-nosed snake)		R
Salvadora hexalepis (desert patch-nosed snake)		R
Salvadora sp. (patch-nosed snake)	P	
Diadophis punctatus (ringneck snake)		R
Pituophis melanoleucus (bullsnake)	P	R
Arizona elegans (glossy snake)	P	R
Rhinocheilus lecontei (long-nosed snake)	P	R
Lampropeltis getulus (kingsnake)	P	R
Gyalopium canum (western hook-nosed snake)	P	R
Sonora semiannulata (western ground snake)		R
Chilomeniscus cinctus (banded burrowing snake)		R
Trimorphodon biscutatus (lyre snake)	P	R
Hypsiglena torquata (night snake)	P	R
Tantilla nigriceps (Plains black-headed snake)		R
Tantilla atriceps (Mexican black-headed snake)		R
Elapidae		
Micruroides euryxanthus (Arizona coral snake)		R
Crotalidae		
Crotalus atrox (western diamondback rattlesnake)	P	R
Crotalus molossus (black-tailed rattlesnake)		R
Crotalus scutulatus (Mojave rattlesnake)	P	R
Crotalus viridis (Arizona black rattlesnake)		R
Crotalus willardi (ridge-nosed snake)	P	
Aves		
Phasianidae		
Colinus gambelii (Gambel's quail)	P	
Colinus sp. (quail)	P	
Cyrtonyx montezumae (harlequin quail)	P	
Meleagridae		
Meleagris gallopavo (wild turkey)		R
Columbidae		
Zenaida cf. *Z. macroura* (mourning dove)	P	
Strigidae		
Otus sp. (screech owl)	P	
Micrathene whitneyi (elf owl)	P	
Asio otus (long-eared owl)	P	
Caprimulgidae		
genus and species indeterminate (night jar)	P	
Picidae		
Colaptes auratus (flicker)	P	
Turdidae		
Turdus cf. *T. migratorius* (American robin)	P	
Catharus guttatus (hermit thrush)	P	
Fringillidae		
Icterinae, genus and species indeterminate (blackbird)	P	
Emberizinae, genus and species indeterminate (sparrow)	P	
Mammalia		
Soricidae		
Notiosorex crawfordi (desert shrew)	P	R
Phyllostomatidae		
Macrotus californicus (California leaf-nosed bat)		R
Choeronycteris mexicana (Mexican long-tailed bat)		R
Leptonycteris nivalis (long-nosed bat)		R
Vespertilionidae		
Myotis yumanensis (Yuma Myotis; bat)		R
Myotis velifer (cave Myotis; bat)		R
Myotis californica (California Myotis; bat)		R
cf. *Myotis* sp. (mouse-eared bat)	P	
Pipistrellus hesperus (western pipistrella; bat)		R
Eptesicus fuscus (big brown bat)		R
Lasiurus borealis (red bat)		R
Antrozous pallidus (pallid bat)	P	R
Molossidae		
Tadarida brasiliensis (Mexican free-tailed bat)		R
Tadarida femorosacca (pocketed free-tailed bat)		R
Eumops perotis (western mastiff bat)		R
Megatheriidae		
Nothrotheriops shastensis (Shasta ground sloth)	P	
Leporidae		
Lepus alleni (antelope jackrabbit)		R
Lepus californicus (black-tailed jackrabbit)		R
Lepus sp. (jackrabbit)	P	
Sylvilagus audubonii (desert cottontail)		R
Sylvilagus sp. (cottontail)	P	
Sciuridae		
Cynomys ludovicianus (black-tailed prairie dog)		R
Spermophilus mexicana (Mexican ground squirrel)	P	
Spermophilus spilosoma (spotted ground squirrel)	P	R
Spermophilus variegatus (rock squirrel)	P	R
Spermophilus sp. (ground squirrel)	P	
Ammospermophilus harrisii (antelope ground squirrel)	P	R
Geomyidae		
Thomomys bottae (valley pocket gopher)	P	R
Thomomys sp. (pocket gopher)	P	
Heteromyidae		
Perognathus flavus (silky pocket mouse)	P	R
Perognathus baileyi (Bailey's pocket mouse)		R
Perognathus hispidus (hispid pocket mouse)		R
Perognathus penicillatus (desert pocket mouse)		R
Perognathus intermedius (rock pocket mouse)		R
Perognathus sp. (pocket mouse)	P	
Dipodomys spectabilis (banner-tailed kangaroo rat)	P	R
Dipodomys merriami (Merriam's kangaroo rat)	P	R
Dipodomys ordii (Ord's kangaroo rat)	P	R
Castoridae		
Castor canadensis (beaver)		R
Cricetidae		
Onychomys leucogaster (northern grasshopper mouse)	P	R
Onychomys torridus (southern grasshopper mouse)		R
Reithrodontomys montanus (Plains harvest mouse)	P	R
Reithrodontomys megalotis (western harvest mouse)	P	R
Reithrodontomys fulvescens (fulvous harvest mouse)		R
Baiomys taylori (northern pygmy mouse)		R
Peromyscus eremicus (cactus mouse)		R
Peromyscus maniculatus (deer mouse)		R
Peromyscus leucopus (white-footed mouse)		R
Peromyscus sp. (deer mouse)	P	
Sigmodon curtisi (cotton rat)	P	
Sigmodon hispidus (hispid cotton rat)		R
Sigmodon minimus (least cotton rat)		R
Sigmodon sp. (cotton rat)	P	
Neotoma albigula (white-throated wood rat)	P	R
Neotoma sp. (wood rat)	P	
Ondatra zibethicus (muskrat)		R
Microtus sp. (vole)	P	
Erethizontidae		
Erethizon dorsatum (porcupine)		R
Canidae		
Canis latrans (coyote)		R
Canis lupus (gray wolf)		R
Canis sp. (wolf)	P	
Vulpes macrotis (kit fox)		R
Urocyon cinereoargenteus (gray fox)		R
Ursidae		
Ursus americanus (black bear)		R
Ursus horribilis (grizzly bear)		R
Procyonidae		
Bassariscus astutus (ringtail)	P	R
Procyon lotor (raccoon)		R
Mustelidae		
Taxidea taxus (badger)		R
Spilogale putorius (spotted skunk)	P	R
Mephitis mephitis (striped skunk)		R
Mephitis macroura (hooded skunk)	P	R
Conepatus mesoleucus (hog-nosed skunk)		R
Felidae		
Felis onca (jaguar)		R
Felis concolor (mountain lion)	P	R
Felis (Lynx) rufus (bobcat)		R
Felis sp. (cat)	P	
Mammutidae		
Mammut americanum (mastodon)	P	
Elephantidae		
Mammuthus columbi (elephant)	P	
Equidae		
Equus sp. (horse)	P	

Table 3, continued.

Tapiridae		
Tapirus sp. (tapir)	P	
Tayassuidae		
Pecari tajacu (javelina)		R
Camelidae		
Hemiauchenia sp. (llama)	P	
Camelops sp. (camel)	P	
Cervidae		
Odocoileus hemionus (mule deer)		R
Odocoileus virginianus (whitetail)		R
Odocoileus sp. (deer)	P	
Antilocapridae		
Antilocapra americana (pronghorn)		R
Bovidae		
Euceratherium collinus (shrub ox)	P	
Bison sp. (bison)	P	

Desert (e.g., paloverde and saguaro) were absent (Van Devender, 1977; Van Devender and Spaulding, 1979). Van Devender suggested that the desertscrub vegetation so characteristic of modern floras in southern Arizona and northern Mexico did not develop until about 8,000 years ago. Prior to that time, these areas might have been grasslands bordered by woodlands—habitats comparable to those now seen in the Lochiel Valley to the west, the Cananea Valley to the south, and the higher foothills bordering the San Pedro Valley. Unfortunately, fossilized packrat middens have not been studied from the San Pedro Valley, although they are known from areas that bracket it—the Rio Grande Valley of west Texas and the Sonoran Desert of western Arizona.

Van Devender (1977) attributed the climatic-vegetational change that occurred 8,000 to 10,000 years ago to a shift in atmospheric circulation due to melting of continental glaciers. The last full glacial period was about 18,000 years ago, during the late Pleistocene. The transition between glacial and Holocene climates was gradual, probably occurring over an interval of several thousand years. Woodland communities gradually died out in the areas now occupied by the Chihuahuan and Sonoran Deserts since about 8,000 years ago. Modern desertscrub communities developed since about 10,000 years ago, and less than 5,000 years ago in some areas (Van Devender, 1977; Van Devender and Spaulding, 1979).

Ponding near Murray Springs, as shown in Holocene sediments and pollen, probably reflects local drainage, rather than a widespread, persistently wetter climate. Pollen has also shown that desertscrub vegetation probably became dominant in the Murray Springs area about 1,000 to 2,500 years ago. Climatic changes were clearly gradual, occurring over thousands of years.

Compared to the late Pleistocene, freshwater molluscs were less diverse in the San Pedro Valley during the Holocene. It is interesting that the number of species that now live in the valley, but have no fossil record (18), almost equals the number of species in the fossil record that no longer live in the valley (16; Mead, 1977). This suggests faunal replacement, possibly due to a climatic shift, but may only represent sampling bias.

Few Holocene vertebrate fossils have been found in the San Pedro Valley. Paleontologists assume that most, if not all, of the vertebrates that live in the valley today also lived there during the Holocene.

Modern Life

The vegetation of the Chihuahuan Desert is rather unique and differs from that of the Sonoran Desert, which lies across the mountains to the west. The Chihuahuan Desert, where shrubs and grasses are dominant, is generally higher and colder than the Sonoran Desert, where shrubs and small-leaved trees are dominant. The vegetation of the San Pedro Valley includes shrubs (tarbush, catclaw, creosotebush, sandpaperbush, and Chihuahuan whitethorn); grasses (grama, muhly, tobusa, sacaton, and needlegrass); and trees (blue paloverde and mesquite); as well as yuccas, sotol, cholla, ocotillo, and pincushion cactus (Lowe, 1964). The climate is arid and generally hot, with irregular summer and winter rainfall.

This vegetation and climate support a diverse group of freshwater molluscs. "To the malacologist" (zoologist who studies molluscs), "Arizona is the land of *Sonorella*," a large terrestrial snail (Bequaert and Miller, 1973, p. 19). Miller (1968) recognized 68 species of *Sonorella*, 57 of which are found in Arizona. The center of species diversity for *Sonorella* is in or near the San Pedro Valley. It is puzzling that *Sonorella* fossils have not appeared in late Pleistocene or Holocene records near Murray Springs, where diverse molluscan fauna have been found. This suggests that *Sonorella* migrated to southeastern Arizona within the last 10,000 years, found a favorable environment, and diversified at an explosive rate. On the other hand, *Sonorella* has a very thin shell, so its absence from the Pleistocene and Holocene records may result from poor preservation in sediments.

Fishes in the San Pedro Valley have been victims of the fluctuating discharge of the San Pedro River. The Colorado squawfish, flannelmouth sucker, and desert pupfish have virtually become extinct in the valley, although they thrived there prior to 1860, as evidenced in historical records. Captain Philip St. George Cooke and his "Mormon Battalion," a group of 500 volunteers who blazed a wagon trail from New Mexico to San Diego, camped in the San Pedro Valley in December 1846. They reported "fish in abundance," some of which were 18 inches long. (Actually, they mentioned catching fish that were 3 feet long, but this may be just a fish story.) This species was probably the Colorado squawfish. They also mentioned finding large herds of wild cattle, plenty of pronghorn antelope, and some bear in the southern San Pedro Valley (Davis, 1982).

Among the amphibians that inhabit the valley, spadefoot toads and several other species of toad (*Bufo*) are common in the wetter habitats. Tree frogs and leopard frogs are not very common, although leopard frogs are locally common along the river. Though well-documented in the fossil record, mud turtles, box turtles, and tortoises are rare inhabitants of the valley today.

A wide variety of lizards and snakes live in the valley and surrounding mountain ranges. The Gila monster and banded gecko are rare. At least 16 species of iguanid lizards are known. Perhaps the most common lizards, however, are the whiptails, with three species now thriving and a fossil record that extends to the valley's early history (e.g., the Quiburis Fm.). Skinks are secretive and rare and are confined primarily to upland canyon habitats. Blind snakes are also very rare. Colubrid snakes, most of which are nocturnal, are very diverse, with 15 genera and 20 species living in the valley. Rattlesnakes are both common and diverse, with four species present.

Birds have been excluded from this part of the wildlife survey because the San Pedro Valley is part of the Pacific Flyway for birds; many birds encountered in the valley are visitors or only temporary residents. Monson and Phillips (1976) identified 432 species of birds in Arizona, almost any of which can be found in the San Pedro Valley at some time during the year. The late Pleistocene record of birds from Deadman Cave (13 species, listed in Table 3) probably represent the closest approximation to the "natural" bird fauna of the valley. Wild turkeys were common in the valley prior to 1865 (Davis, 1982).

Small mammals thrive in the valley. The only shrew living there today is the desert shrew, a common but secretive animal. Bats are diverse; 10 genera and 13 species have been identified. Rabbits, both the jackrabbit and the cottontail, are common in the valley. Four species of squirrels have been found, but none are widespread or common. Pocket gophers abound and are very diverse at the subspecies level. Pocket mice and kangaroo rats are also plentiful. Beavers were trapped in the San Pedro River in historical times, and might have been an important food source for early Indians (Davis, 1982). By about 1835, however, beavers were essentially "trapped out." They are seldom, if ever, seen there now.

Seven genera and 13 species of cricetid rodents inhabit the San Pedro Valley today. This diversity is common in similar habitats in North America. Cricetid rodents are small and reproduce rapidly; they are probably the most significant mammals in terms of biomass. Cricetid rodents were common in the valley since its beginning.

The porcupine and coyote are common inhabitants, the latter being the most frequently sighted (and heard) wild mammal in the valley. Wolves, like beavers, were common in historical times, but are now virtually extinct in the valley. Foxes are rare. Ringtails and raccoons are relatively common but rarely seen, because they are mostly nocturnal. Badgers are rarely seen; their presence, however, is recorded in tracks, burrows, and scats. Skunks are present, but uncommon.

Jaguars are probably extinct in the San Pedro Valley, but still live in Sonora, to the south. A jaguar might occasionally roam the valley in search of food, but would soon return to its homeland. The mountain lion is more likely to be seen in the valley; the bobcat, even more so.

Javelinas are abundant and widespread in the valley, except during hunting season. About 500 to 800 javelinas are sighted annually. They were commonly encountered in the San Pedro Valley during the 1800's. The mouth of the San Pedro River was called "Hog River" in 1846 (Davis, 1982, p. 28).

Mule deer outnumber whitetails by about 5 to 1. The annual census by the Arizona Game and Fish Department shows significant fluctuations in the number of deer in the valley over a 10-year period. Food and shelter appear to be the most significant factors controlling deer populations.

Pronghorns and bears (black and grizzly) lived in the valley prior to its settlement by miners and farmers after the Civil War. They no longer live in the valley, although black bears still inhabit the surrounding mountains.

The absence of beavers, bears, and pronghorns from their former habitats in the valley is most likely a consequence of man's activity, especially farming. Climatic changes are probably responsible for most other floral and faunal changes.

SUMMARY

The San Pedro Valley was formed during the late Miocene Basin and Range disturbance, between 14 and 6 m.y. ago. Knowledge of the terrane in southeastern Arizona prior to this period of geologic disruption is very limited. A diversity of plants and animals inhabited the San Pedro Valley during the last 6.5 m.y. The valley contains the best documented sequence of late Cenozoic life in Arizona and one of the best in North America.

During the late Miocene and Pliocene, fine-grained deposits accumulated in the center of the San Pedro Valley. This occurrence reflects internal drainage, or incomplete integration of the drainage system. Diatoms, ostracods, molluscs, and small vertebrate remains were preserved in these fine-grained deposits. Many birds, including shore birds, were also preserved. Mammals that inhabited the valley during the late Tertiary include shrews, bats, glyptotheres, rabbits, rodents, dogs, cats, skunks, bears, raccoons, gomphotheres, mastodons, horses, peccaries, camels, deer, and pronghorns. Complete integration of drainage in the valley probably did not occur until about 1.5 m.y. ago, near the Pliocene/Pleistocene boundary.

The San Pedro Valley has one of the best terrestrial sequences in North America for correlation with the Pliocene/Pleistocene boundary, and thus, is a key North American reference section for this boundary. Because of its diverse mammal fauna, the valley helps to clarify mammal evolution and intercontinental dispersal during the last 6 m.y.

A number of important events occurred in the San Pedro Valley near the end of the Pleistocene, the most notable of which was the appearance of early man. The San Pedro Valley has yielded one of the best records of early man and extinct mammals in North America. The late Pleistocene record in the valley is truly remarkable, and promises to yield even more information about early man, extinct mammals, and vegetational changes.

Climatic change during the Pleistocene and Holocene had profound effects on vegetation and animals in the San Pedro Valley. Woodlands were very common in the lower valleys of southeastern Arizona during the Pleistocene. The desert vegetation of present-day southern Arizona developed only during the last 10,000 years. The timing and magnitude of these climatic changes are just beginning to be understood.

The San Pedro Valley preserves a rich history of late Cenozoic geology and life. This history, as well as its relation to global climatic changes, can be better understood through the fossil record preserved in the valley's sediments.

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(continued on page 12)

Arizona's Metallic Mineral Districts: A Wealth of Information

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This summary is provided to acquaint members of the exploration community, from prospectors to professionals, with recently compiled information and some current projects at the Arizona Bureau of Geology and Mineral Technology.

With the release of Bulletin 194, *Metallic Mineral Districts and Production in Arizona* (Keith and others, 1983a), the Bureau expands its role in investigating Arizona's mineral resources. In Bulletin 194, known metallic mineral occurrences are divided into discrete metallogenic groups of similar age and style of mineralization. This effort was prompted by the need to define *mineral districts* according to geologic criteria rather than the traditional geographic association of mines used in the standard *mining district* classification.

Bulletin 194 serves as the baseline for Bureau research in economic geology. It provides production statistics for most of the mineral districts outlined on its map. Production data include metals recovered from milled ore, minor, directly smelted ore, and reworked tailings. Because many of the metallic mineral occurrences are poorly understood, mineral-district boundaries could change as knowledge of the deposits and geologic settings improves. Bulletin 194 may be inspected at or purchased from the Bureau ($6.50, plus $2.00 for shipping and handling).

Two companion products augment the information in Bulletin 194. U.S. Geological Survey (USGS) Open-File Report 84-0086 (Keith and others, 1983b) provides terse descriptions of geologic settings and an extensive list of references for Arizona's mineral districts. The open-file report may be inspected in the Bureau library or purchased from Open-File Services Section, Western Distribution Branch, U.S. Geological Survey, Box 25425, Federal Center, Denver, CO 80225. The bibliographic information is undergoing further review and will probably be published by the Bureau on a county-by-county basis. Another supplement to Bulletin 194, now being compiled, lists ore grades from individual mineral districts. The Bureau will release this information as an open-file report.

In addition to mineral-district information, the Bureau has geologic information on mines in Arizona that have produced more than 100 tons of ore. Bureau staff, under contract to the USGS, compiled the Arizona portion of the Mineral Resource Data System (MRDS). This section includes nearly 3,300 records with information on the location, geology, and production of metallic mineral commodities. Individual mines are grouped according to the mineral-district classification of Keith and others (1983a,b). The records, of variable quality, contain summaries of information available in published literature, private reports and files, and field examinations. Peterson (1984) gives a more complete description of the MRDS data for Arizona. A copy of the Arizona MRDS data may be inspected in the Bureau library or obtained from the USGS. A subset of MRDS pertaining to molybdenum occurrences in Arizona has been placed on open file by the U.S. Geological Survey and is also available for inspection at the Bureau (Wilt and others, 1984).

All mines and prospects in Arizona, regardless of known production, are recorded in the U.S. Bureau of Mines (USBM) Minerals Industry Location Subsystem (MILS). The Arizona portion of MILS was compiled by subcontractors to the Arizona Department of Mines and Mineral Resources (ADMMR), under contract to the USBM. MILS, a subset of MAS (Minerals Availability System), lists deposit name and synonyms, precise location, type of operation, and current status for each mine. Although it does not furnish geologic information, MILS can be useful in locating obscure mining properties. MILS data for Arizona may be inspected in the Bureau library or obtained from the USBM or ADMMR.

The Bureau recently released map compilations that are of use to the mineral-exploration community. A geologic-map index (Scarborough and Coney, 1982) provides location information for more than 550 references concerning geologic mapping in Arizona. The index may be inspected at or purchased from the Bureau ($5.00, plus $1.50 for shipping and handling). An update through June 1984 (Scarborough and McGarvin, 1984) is also available ($2.00, plus $1.50 for shipping and handling). Newly published Map 19 (Keith, 1984), a map of outcrops of Laramide (Cretaceous-Tertiary) rocks in Arizona and adjacent regions, is now available from the Bureau ($3.00, plus $1.50 for shipping and handling). This map delineates the known occurrences of Laramide-age rocks in Arizona, and should help to define prospective areas of igneous rocks within the State.

Bureau files contain a wealth of information about the geology of Arizona's metallic mineral occurrences. Bureau staff are working to make these data useful to mineral-exploration personnel. One current project is a report, entitled "Geology of Mid-Tertiary Mineral Districts in Arizona." The report summarizes the geology, age, style of mineralization, current production value, and ore grade for each Arizona mineral district of presumed mid-Tertiary age.

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USGS Director Visits Tucson

Dr. Dallas L. Peck, Director of the U.S. Geological Survey, visited the University of Arizona September 25-26, after speaking at the annual meeting of the American Mining Congress in Phoenix. His visit was arranged by Dr. Orlo E. Childs, Director of the Arizona Mining and Mineral Resources Research Institute.

While at the university, Dr. Peck met with faculty and students in the Department of Mining and Geological Engineering, the Department of Geosciences, and the Bureau of Geology and Mineral Technology. He also gave a talk on U.S. Geological Survey research and activities designed to provide better understanding and identification of mineral resources. Excerpts from his talk are included in the following paragraphs.

In the Organic Act of 1879, the U.S. Geological Survey (USGS) was given the responsibility to conduct "an examination of the geological structure, mineral resources, and products of the public domain." Since then, the Survey's responsibilities have been broadened to provide scientific leadership in programs that support exploration for domestic minerals, especially strategic and critical minerals, and to assess the Nation's mineral resources, particularly on Federal lands.

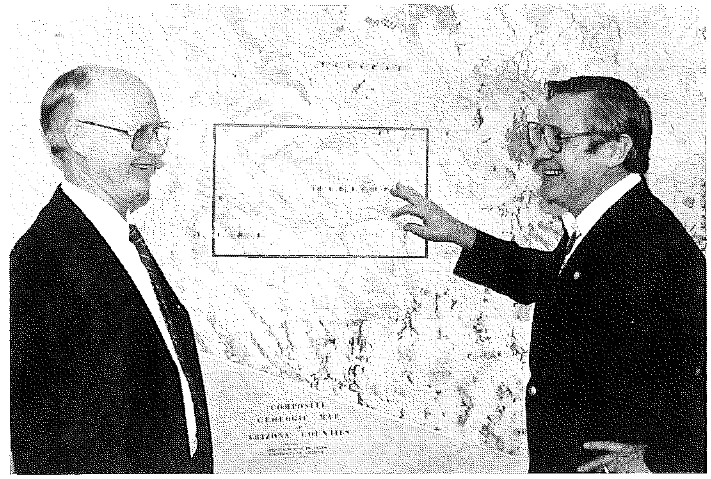
The role of the USGS in geologic studies is usually one that is regional in scale, fundamental in scope, and practical in application, and does not include government exploration and subsequent leasing. Work is directed toward developing an understanding of the regional geologic framework and providing basic data such as topographic and geologic maps. Some projects bridge the gap between fundamental and applied geologic research; some increase understanding of ore genesis and determine how this knowledge can be used to find new deposits.

The USGS has three main programs for evaluation of the Nation's mineral resources: the Conterminous United States Mineral Assessment Program (CUSMAP), the Alaska Mineral Resource Assessment Program (AMRAP), and the Mineral Resources of Public Lands (MRPL). In the CUSMAP and AMRAP programs, areas of 5,000 to 8,000 square miles, outlined in 1:250,000-scale quadrangle maps, are being evaluated for their mineral potential. Existing data are integrated with new data gathered during geologic, geochemical, geophysical, and remote-sensing studies. To date, 175,000 square miles have been surveyed in Alaska, and 80,000 square miles have been covered in the conterminous States.

Approximately 600,000 square miles are scheduled to be assessed by the year 2000 in Alaska; almost a million square miles will be assessed in the conterminous States during the next several decades. The MRPL program is responsible for evaluating wilderness lands administered by the U.S. Bureau of Land Management, the U.S. Forest Service, and other land-management agencies. Under the provisions of the Wilderness Act and subsequent related legislation, these assessments are to be made by the U.S. Geological Survey and the U.S. Bureau of Mines.

The Federal Mineral Land Information System (FMLIS), a new digital information system that is being developed and evaluated by the USGS, will allow land managers, policy makers, and others to retrieve up-to-date minerals information concerning Federal lands. The data base will contain information on surface ownership, subsurface mineral rights, restrictions to mineral development, and published data on mineral occurrence and mineral-resource potential. The USGS and other Federal agencies are developing procedures for attainment of an operational system by FY 1986.

The USGS, traditionally committed to basic geologic mapping, has proposed a new program for FY 1985: the Federal/State Cooperative Geologic Mapping Program (COGEOMAP). The objective of this program is to increase production of geologic and geophysical maps



Dr. Larry D. Fellows, State Geologist and Assistant Director, Arizona Bureau of Geology and Mineral Technology (left), and Dr. Dallas L. Peck, Director, U.S. Geological Survey, discussing COGEOMAP project in the Phoenix 1° x 2° quadrangle. Photo: K. Matesich.

in States that place a high priority on obtaining baseline information. The program is designed so that the USGS and State geological surveys, both of which have statutory responsibilities for geologic mapping, can work together on a 50-50 basis. Thirty-five State geological surveys, including Arizona's (the Geological Survey Branch of the Bureau of Geology and Mineral Technology), have submitted proposals to participate in COGEOMAP. Arizona has proposed to do geologic mapping in the Phoenix 1° x 2° quadrangle.

In the realm of process studies, one of the most exciting areas of future USGS research is in the role of organic material in the formation and detection of ore deposits. Studies are needed to understand how organic material picks up metals, transports them, removes them from solution, and concentrates them into ore. With this understanding, more effective tools for finding concealed deposits can be developed.

The USGS is developing technology to enhance detection of unexposed mineral deposits. One method is to identify the presence and geometry of a paleothermal anomaly associated with an ore deposit. Changes in conodont color, abundance of fission tracks, crystallinity of clays and feldspars, pyrolysis of organic matter, and orientation of paleomagnetic direction are being studied as a means to detect the paleothermal anomaly associated with an unexposed former heat source such as a stock or hydrothermal plumbing system. Although the effects of heat and hot water in this larger paleothermal aureole may be nearly invisible, they may still reflect the presence of a concealed mineral deposit. Because the anomaly is larger than the target, the chances of finding the deposit are substantially improved. In addition, such an anomaly would have manifestations of thermal gradient *within it*, thus providing vectors toward the target.

Other USGS research focuses on new geophysical techniques for detection of ore deposits, such as airborne gravity surveying; laser-stimulated, infrared remote-sensing; and studies of changes in the earth's electrical and magnetic fields caused by interaction of the fields produced by hidden ore deposits and power-transmission lines. Current research in geochemical exploration includes studies of vegetational changes caused by absorption of certain metals. Quick, reliable, inexpensive methods are being developed to detect the presence of microbiological organisms, gases, thermal inertia, and spectral radiation over buried deposits. Much of this methodology is directly transferable to industry-sponsored exploration programs.

One of the most important responsibilities of the USGS is coordination and communication with industry and academia. Although the USGS communicates much of its data to the public via maps and reports, public meetings provide a more timely means to convey information and allow USGS scientists to confer with industrial and academic colleagues on a one-to-one basis. One such meeting, held in November 1983 in Reston, Virginia, focused on the National Program for the Assessment and Development of the Mineral Resources of the United States Exclusive Economic Zone. The proceedings of that meeting are now available, free of charge, as USGS Circular 929.

A Petroleum Research Symposium was held October 10-11, 1984 at the Colorado School of Mines in Golden. Discussions included the status of current topical research and resource studies of onshore and offshore basins.

A public meeting for the Alaska Mineral Resource Assessment Program, planned for March 1985, will feature continuing USGS work in the Seward Peninsula and western Brooks Range. These areas are the focus of considerable industry exploration and predevelopment activity for precious, base, and strategic metals.

The first McKelvey Forum on USGS Research on Mineral and Energy Resources, entitled "Research in Mineral Resources—1985," will be held February 6-7, 1985 at the Regency Inn in Denver. The symposium will be an annual event to present results of USGS research in mineral and energy resources to the industrial and academic communities. This year's topics include regional syntheses, district studies, topical studies of ore-forming processes, and new resource-assessment techniques. All interested persons are invited.

GEOSCIENCE DAZE COLLOQUIUM

The students of the Department of Geosciences, University of Arizona, will be holding their 13th annual *Geoscience Daze* on March 27-29, 1985, in the Student Union Senior Ballroom. More than 40 papers will be presented on various aspects of geosciences. The public is cordially invited; admission is free. For more information, contact Nancy Hess, Geoscience Daze Chairperson, 318I Geology Bldg., Univ. of Arizona, Tucson, AZ 85721; (602) 621-6002.

(continued from page 9)

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Fieldnotes

Volume 14 No. 4 Winter 1984

State of Arizona .... Governor Bruce Babbitt
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Industrial Minerals Forum Coming to Tucson

The 21st annual Forum on the Geology of Industrial Minerals is coming to Tucson. The meeting, to be held April 9-12, 1985, is being hosted by the Geological Survey Branch of the Arizona Bureau of Geology and Mineral Technology. Wes Peirce, Principal Geologist with the Bureau, is the general chairman of the forum.

The forum was initiated 21 years ago by Robert L. Bates, whom many will recognize as the author of "The Geologic Column," which appears monthly in *Geotimes*. Most participants in past years have been from the East and Midwest, where nonmetallic materials are of supreme importance. Regular forum participants have something else in common: they abhor formality, an aversion that has made previous forums enjoyable, as well as enlightening.

The Tucson meeting will consist of field trips on April 9th, a full day of papers on the 10th, a full-day field trip on the 11th with a banquet at night, and papers on the morning of the 12th.

Concurrent field trips on the 9th will include a half-day (a.m.) visit to a local copper mine-mill complex for those who are unfamiliar with this aspect of Arizona mining, and a full-day trip to the Bowie zeolite deposits. April 10th and the morning of the 12th will be devoted to papers on industrial minerals of the Southwest, including overviews of Arizona, Nevada, Utah, and Mexico. Many of the papers, however, will focus on Arizona's industrial rocks and minerals. The Bureau will subsequently publish papers presented at the forum.

The all-day trip on the 11th, a scenic drive through Mammoth, Winkelman, Superior, and Globe, will include stops at selected sites that feature industrial minerals and copper operations. A banquet will be held that evening at the Holiday Inn Broadway in Tucson. The program will include a slide show on Arizona, set to music, by freelance photographer Peter Kresan.

The forum is open to all professionals in the industrial minerals field, and to their spouses. (There will be spouse activities.) First notices of the meeting have already been mailed to likely participants. If you have not received a notice, but are interested in attending the forum, please contact Wes Peirce, Arizona Bureau of Geology and Mineral Technology, 845 N. Park Ave., Tucson, AZ 85719; telephone: (602) 621-7906. To participate in this meeting, registration is required; preregistration is preferred.

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